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Dracontium nivosum (Lem.) G.H.Zhu (Araceae): range extension from Amazonia to a *brejo* forest refugium in Northeast Brazil confirmed

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Abstract: The 558 km range extension of the Amazonian aroid *Dracontium nivosum* (Lem.) G.H.Zhu into semi-arid Northeast Brazil is confirmed. This species occurs in Ceará in threatened fragments of *brejo* forest at ca. 580–870 m elevation. An illustrated taxonomic description is provided. The species' Extent of Occurrence (EOO) is estimated as 356,392 km^2 (meets Least Concern); the Area of Occupancy (AOO), 60 km^2 using a 2×2 km cell (Endangered). Within Ceará the EOO is 41.4 km^2 (Critically Endangered) and the AOO is 16 km^2 (Endangered).

Key words: Chapada da Ibiapaba; range extension; threatened forest fragments; semi-arid Neotropics; conservation status; spatial analysis; Ceará

The aroid genus *Dracontium* L. consists of 26 species (Zhu and Croat 2004; WCSP 2016), of which 13 occur in Brazil (Calazans and Soares 2016). No species was known from semi-arid northeast Brazil until our 2002 discovery of a plant we identified provisionally as *D. nivosum* (Lem.) G.H. Zhu. This was found in a humid upland forest fragment in the Chapada da Ibiapaba, Ceará state. *Dracontium nivosum* was previously known only from Pará and western Maranhão states in Amazonia. The present report confirms our initial determination from new field collections that flowered in cultivation and have been preserved in alcohol. A detailed description of this material allows a more critical comparison with previous taxonomic treatments. With the aid of geographical data from other reliably identified collections of the species (speciesLink 2015), a spatial analysis was carried out using the Geocat online tool (Bachman et al. 2011). Although this analysis resulted in a conservation assessment of Least Concern (LC) for *D. nivosum* over its whole range, we assess the newly confirmed populations in Ceará as Critically Endangered (CR) based on Extent of Occurrence (EOO) and Area of Occurrence (AOO). This assessment is further reinforced by continuing human pressures on the very small surviving forest fragments where these populations occur.

The populations recorded from Ceará occur in the municipalities of Viçosa do Ceará and Tianguá in the northern part of the Chapada da Ibiapaba, a major upland that runs north to south along the western border of the state. These populations form the basis of our species description and the herbarium voucher specimens we made from them are detailed in Table 1, together with those of the other reliable records of *D. nivosum* used in this study, obtained from the SpeciesLink online database (*species*Link 2015). The latter includes almost all the specimens on which the standard taxonomic treatment of the species was based (Zhu and Croat 2004). The determinations of the specimen records obtained from SpeciesLink were made by acknowledged taxonomic specialists of the family Araceae. The distribution map was made using the online software SimpleMappr (Shorthouse 2010). Spatial analysis and IUCN conservation assessments were made using the online interactive GeoCat tool (Bachman et al. 2011).

Cultivation of field-collected material is almost always needed for adequate descriptions of *Dracontium* species. The taxonomic delimitation and identification of the species are based largely on reproductive characters, particularly of the peduncle, spathe, spadix and seeds (Zhu and Croat 2004), but plants occur sparsely in natural

Table 1. Distribution of *Dracontium nivosum* (Lem.) G.H.Zhu based on specimen records in the SpeciesLink database (SpeciesLink 2015). Extra locality details are provided for the voucher specimens from Ceará, as these document the populations described in detail in this paper.

Latitude (decimal degrees)	Longitude (decimal degrees)	Brazil state	Altitude (m)	Collector and number	Date of collection	Herbarium	Determiner
–04.124	–054.998	Pará	90	Black, G.A. 47-2084	28 December 1947	MOBOT-BR	Zhu, G.H.
–04.124	–054.998	Pará	90	Black, G.A. 47-2084	28 December 1947	MOBOT-BR	Zhu, G.H.
–04.124	–054.998	Pará	90	Black, G.A. 47-2084	28 December 1947	RB	Nadruz, M.A.
–02.443	–054.708	Pará	53	Gonçalves, E.G. 1074	16 January 2003	CVJBFZB	Gonçalves, E.G.
–02.498	–054.309	Pará	32	Ginzberger 359	16 June 1927	MOBOT-BR	Zhu, G.H.
–02.498	–054.309	Pará	32	Hagmann, G. 360	?	MOBOT-BR	Zhu, G.H.
–03.718	–053.737	Pará	148	Gonçalves, E.G. 1090	18 January 2003	CVJBFZB	Gonçalves, E.G.
–03.750	–049.667	Pará	23	Plowman, T. et al. 9895	22 March 1980	MOBOT-BR	Zhu, G.H.
–03.500	–049.500	Pará	75	Machiel & Rosario 534	15 March 1981	MOBOT-BR	Zhu, G.H.
–01.500	–048.667	Pará	11	Anné Gely 234	19 March 1985	MOBOT-BR	Zhu, G.H.
–00.857	–048.142	Pará	5	Black, G.A. 18814	1 August 1955	MOBOT-BR	Zhu, G.H.
–00.857	–048.142	Pará	5	Black, G.A. 18814	1 August 1955	MOBOT-BR	Zhu, G.H.
–00.750	–048.033	Pará	14	Lobato, L.C.B. et al. 60	22 February 1985	MOBOT-BR	Zhu, G.H.
–01.057	–046.786	Pará	29	Mehlig, U. 1602	21 March 2015	HBRA	Mehlig, U. *
–01.057	–046.786	Pará	29	Mehlig, U. 1505	2 October 2014	HBRA	Mehlig, U. *
–03.117	–046.083	Maranhão	61	Balee, W. 3476	24 June 1987	MOBOT-BR	Zhu, G.H.
–03.569	–041.081	Ceará, municipality of Viçosa do Ceará: Pedra do Caranguejo	661	Andrade, I.M. et al. 627	4 March 2002	EAC	Mayo, S.J.
–03.569	–041.081	Ceará, municipality of Viçosa do Ceará: trilha para Pedra do Caranguejo	661	Andrade, I.M. et al. 4330	2 May 2013	HDELTA †	Andrade, I.M.
–03.586	–041.074	Ceará, municipality of Viçosa do Ceará: Lajes	621	Andrade, I.M. et al. 628	4 March 2002	EAC, UFRN	Mayo, S.J.
–03.700	–040.959	Ceará, municipality of Tianguá: Sítio Gameleira	870	Andrade, I.M. et al. 631	6 March 2002	EAC, UFRN	Mayo, S.J.
–03.661	–040.953	Ceará, municipality of Tianguá: Cascata da Serra, subida da serra	587	Andrade, I.M. et al. 635	6 March 2002	EAC, UFRN	Mayo, S.J.

*determination confirmed by SJM from excellent photographs made by U. Mehlig accompanying his specimen (*Mehlig 1505*) in the SpeciesLink database. All other determiners are acknowledged taxonomic specialists of the Araceae.

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The following specimens listed in SpeciesLink were omitted as probably from plants cultivated in association with institutions: J.M. Pires 6594 (MOBOT_BR 885555), R. Lima 108 (MOBOT_BR 885558), Huber 3667 (MOBOT_BR 885545), Huber 2036 (MOBOT_BR 885552).

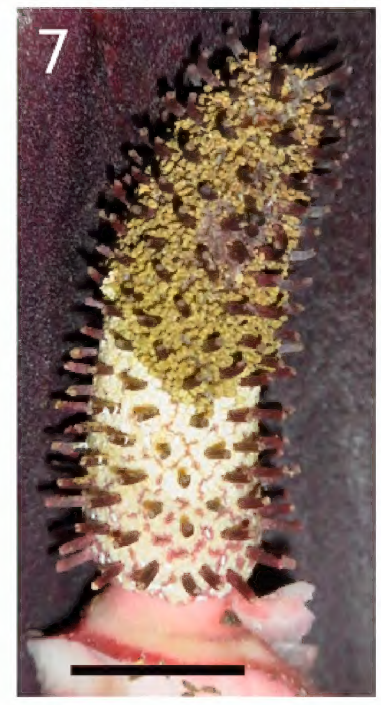
populations and flower before the solitary treelet-like leaf emerges from the underground tuber. The flowering period is short compared to the more conspicuous vegetative phase and consequently plants are usually collected when sterile. Because most species are robust or even gigantic herbs, herbarium specimens normally consist of leaf fragments, while those with well-preserved reproductive organs are few. As a result, knowledge of the range of variation of the critical reproductive characters is very incomplete in *Dracontium*, weakening species delimitation and hampering identification. Useful taxonomic descriptions of species depend largely on bringing cultivated specimens into flower and fruit and these need to be raised from natural populations in order to better understand intra- and inter-specific patterns of morphological variation.

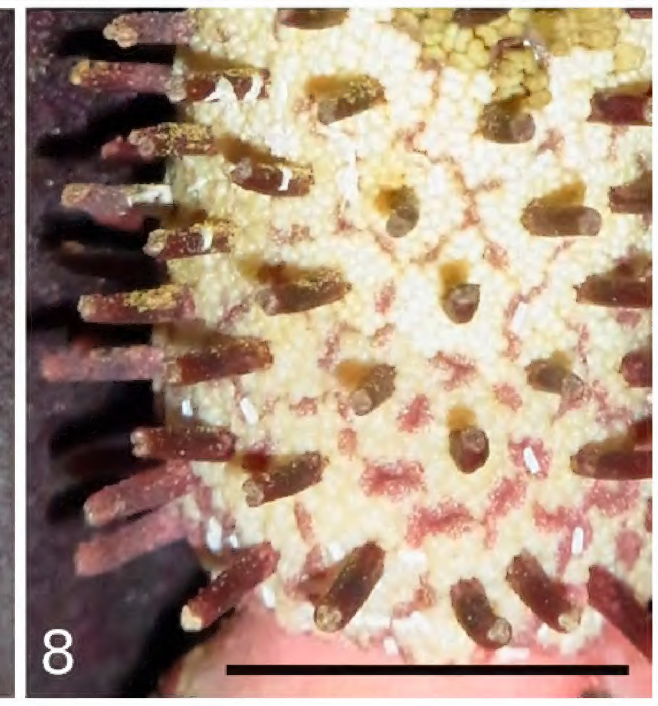
Previous identification of the Ceará collections (reported by Andrade et al. 2013) could only be provisional because it was based on digital images of the inflorescence of a single living collection which flowered in cultivation but was later lost. Most of the critical reproductive characters could not be verified from these images.

New collections, including an infructescence and tubers, were made in 2013 and cultivated at the Universidade Federal do Piauí, Campus Ministro Reis Velloso, Parnaíba. These later provided the flowering material that made possible a critical determination and thus confirmation of the range extension of this species into semi-arid Northeast Brazil.

Comparison of the Ceará plants with the identification key and description of *D. nivosum* provided by Zhu and Croat (2004) showed agreement in the following diagnostic characters: life form terrestrial (not helophytic, Figures 1 and 2); leaflets held more-or-less horizontal or drooping, not linear (Figure 4); peduncle sessile at soil surface or subsessile (up to 2 cm above ground, Figure 6); longest bracteole (preceding the inflorescence) extending to spathe (Figure 6); spathe cymbiform, non-constricted (Figures 5 and 6); spadix lacking apical appendages (Figure 7); styles 4–5.5 mm long and projecting far beyond the tepals and stamens (Figure 8); seeds similar in outline shape (cf. Zhu and Croat 2004: Figure 17C), mid- to light brown, 5–7 mm diameter, almost smooth laterally and with inconspicuous sculpture (Figure 11).

Figures 1–4. *Dracontium nivosum*, vegetative characters. **1**: Habitat at Viçosa do Ceará, first author with recently collected plant in leaf, scale bar = 35 cm. **2**: Basal part of petiole showing dense white stippling superimposed on transverse patterning and distal cataphyll, scale bar = 1 cm. **3**: Mid-part of the petiole showing larger downwardly curved aculeae among smaller projections, scale bar = 1 cm. **4**: Segment of leaf with five terminal lobes seen from above, scale bar = 5 cm.





Figures 5–8. *Dracontium nivosum*, inflorescence and floral characters. **5**: Spathe (male anthesis) seen in ventral view, showing half-exposed spadix, scale bar = 2 cm. **6**: Same as 5, in side view, showing prominent and slightly paler main veins on dorsal surface and long bracteole extending up to spathe base, scale bar = 2 cm. **7**: Spadix at same stage as 5, showing basipetal maturation of the anthers (dehisced anthers in upper half, not yet dehisced in lower half), scale bar = 1.3 cm. **8**: Lower part of spadix showing flowers just before anther dehiscence, pink-purple tepal apices are most visible in basal flowers, scale bar = 1 cm.

Points of disagreement between the Ceará plants and the description of Zhu and Croat (2004) — given here in brackets — are: spathe ca. 17.5 (28–35) cm long; spathe margins overlapping at base for only 2 cm, Figure 5 (overlapping for half spadix length); upper half of spadix exposed at anthesis, Figure 5 (flowering spadix concealed by spathe); flowering spadix 4.2–4.3 cm long, 1.25–1.3 cm diameter, Figure 7 (flowering spadix 5–6.5 cm long, 1.2–1.5 cm diameter); berries black purple to pale brown apically, Figures 9 and 10 (mature berries orange).

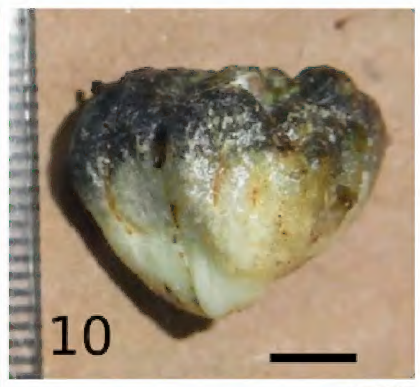
To facilitate critical future comparisons of populations of this species across its range, we present below a detailed taxonomic description of the Ceará populations, made from living material and using the revision of Zhu and Croat (2004) as a guide to character analysis and descriptive format.

Dracontium nivosum (Lemaire 1865: Planche 424) G.H. Zhu (2002: 301). Type: Planche 424 in *L'Illustration Horticole* vol. 12 (1865) (lectotype designated by Zhu and Croat 2004: 638).
= *Amorphophallus nivosus* Lem. (Lemaire 1865: Planche 424).

Robust geophyte of medium to large stature. Stem a flattened-hemispheric tuber up to 33 cm in circumference, 12–13 cm diameter, 6 cm in depth (axial dimension), exterior brown, white within, situated up to 30 cm below soil surface, upper surface flattened producing whitish roots and several to many tubercles, lower surface rounded, rootless. Leaf solitary (Figure 1), preceded by four cataphylls, the last cataphyll much longer than the first three, chestnut to ferrugineous brown, shallowly scabrous in a transverse pattern (Figure 2). Petiole ca. 1.4–2 m long, subcylindric, subterranean part up to 16 cm long, white, smooth, with a short, thick-walled basal sheath, aerial portion ca. 3.5 cm diameter at base, 2 cm diameter in central region, tapering to ca. 1.5–1.2 cm diameter towards apex, patterned in brown purple and white (with slight greenish tinge in most basal portion) in irregular transverse to oblique zones somewhat resembling a snakeskin (Figures 2 and 3),

each transverse zone paler to whitish on the distal side and black to brown purple darker on the proximal side, transverse colour zones much more densely arranged in basal portion, surface of aerial petiole densely scabrous and verruculate, with very short irregular protuberances arranged in ridges along the transverse colour zones, verruculae white-tipped, much denser and more numerous towards petiole base, with sparser, larger, 1–3 mm long, brown-purple to white downwardly curved prickles shaped like claws more numerous and larger in the central part of the petiole (Figure 3), upper half of petiole with transverse zones more spaced out and alternating with smoother areas which vary in colour from purplish to silvery, purple predominating in apical part of petiole, petiole shortly pulvinate at apex and at junction with the three primary rachises of the blade. Leaf blade dracontioid (Figure 1, umbrella-like in overall shape, divided into three more-or-less equal major divisions each of which is further highly subdivided), overall size 100–140 cm long, 120–150 cm wide; rachis of each major division abaxially of same colour and texture as apical portion of petiole, adaxially sulcate with winged margins from which leaflet lobes arise; central major division 75–90 × 70–90 cm, main rachis trichotomously divided twice; lateral major divisions with main rachis twice dichotomous, left-hand major division (seen from above) 60–80 × 56–100 cm, right-hand major division 60 × 54–80 cm; terminal and subterminal leaflets and lobes 8–17 × 4.2–9.3 cm, elliptic to obovate (Figure 4), membranaceous, acuminate, adaxially dark green, with venation (midrib, primary and secondary lateral veins) impressed into the surface and margins shortly undulate, abaxially only slightly paler, venation prominent, midrib whitish, primary lateral veins 6–8 on each side, paler than blade, frequently forming arching infra-marginal collective veins on each side. Inflorescence solitary (Figure 5), appearing before the leaf, probably sessile at soil surface in habitat; peduncle at anthesis 2–3 cm long (Figure 6, cultivated plant), 1.1–1.3 cm diameter at apex, densely transverse-patterned in brown, probably entirely subterranean in the field, preceded by two short broad cataphylls 1.6–2.0 × 1.8–2.0 cm, and finally a larger, smooth, reddish-brown, oblong-elliptic, apiculate cataphyll ca. 5.5 × 3.3 cm, that covers the peduncle and partially covers the lower part of the spathe on the ventral side (where the margins overlap) at anthesis (Figure 6). Spathe (Figures 5 and 6) strongly fornicate, much longer than spadix, ca. 17.5 cm long measured along curve of dorsal side, 10.5 cm long measured on ventral side as a straight line segment from base of spathe margins and across the gape to apex, externally brown tinged olive green becoming reddish-purple at the margins, major longitudinal veins prominent and distinctly paler (Figure 6), internally smooth, uniformly rich darkish purple with a velvety sheen (Figure 5) apart from a narrow white ring at extreme base at junction with spadix and peduncle, margins convolute for ca. 2 cm basally (Figure 5. ca. one ninth of spathe length) to form a stout, shortly cylindric, unconstricted, upright, tubular part ca. 3–3.3 cm long, ca. 3.8–4.0 cm diameter, basal circumference 9 cm, rounded to truncate at base, 0.5 cm thick at junction with peduncle, remainder of spathe (blade) cymbiform, arching strongly forwards so that the apical portion is held ± horizontally, ovate-elliptic and apiculate at tip, gaping widely at anthesis, ca. 14.3 cm long, gape ca. 7.5 cm wide, exposing the upper half of the spadix (Figure 5), semi-circumference of transverse section 11.5 cm. Spadix (Figure 7, at male anthesis) 4.2–4.3 cm long (ignoring styles), ± cylindric, digitiform, slightly bent forward in upper third, 1.3 cm diameter at base and middle, 1.25 cm diameter near apex, either fertile to apex or occasionally with a short zone of atrophied flowers at apex (but not appendages), stipe 0.2–0.25 cm long, whitish. Flowers bisexual, perigoniate, maturing basipetally; tepals free, oblong to spathulate, weakly to distinctly cucullate at apex, 3 × 0.8 mm, purple, with numerous silvery white raphide cells; ripening stamens forming a dense and continuous layer above the tepals (Figures 7 and 8), the distal zone with dehisced stamens slightly thicker than the proximal undehisced zone, anthers pale yellow, filaments 3 mm long, flat, membranaceous, junction with connective marked by a transverse ridge, anther 1–1.3 mm long, 0.8–1 mm wide at apex, thecae distinctly broader at apex, dehiscing by lateral slits from the top downwards; ovary ovoid-cylindric, 1 mm long, 1.7 mm wide, style (Figure 8) purple, 4.7–5.5 mm long, projecting 2–3.5 mm beyond layer of ripening stamens, 1 mm diameter, cylindric, containing numerous silvery white raphide cells, stigma small, whitish, ± punctiform, shallowly and inconspicuously 3–4-lobed, a little narrower than style (but probably wider at female anthesis), ca. 0.8 mm wide. Infructescence (Figure 9) globose or irregularly ovoid, 7–9.5 cm long, 3.5–6 cm maximum width, peduncle extending to ca. 2–3 cm long above soil surface; berries (Figure 10) 3-4-locular, (2–)3–4-seeded, 1–1.3 × 1.3–1.7 cm, roughly rhomboid seen from above, roughly obpyramidal in side view, broader than long, apex much wider, black-purple to pale brown, corrugated and irregularly excavated with bulging locules, with 0.4–0.8 cm long rostrum formed by persistent style (Figure 9), basal part narrowing and green-tinged white; seed reniform (Figure 11), 6–7 × 4.5–5 mm, laterally compressed, ± narrowly elliptic in cross section, mid-brown, mostly smooth, with darker, slightly prominent median ridge next to which lies a series of shallow and inconspicuous bulges.

Dracontium nivosum, a Brazilian endemic, was previously known only from collections in Pará state and a single collection from western Maranhão (Figure 12,



Figures 9–11. *Dracontium nivosum*, fruit and seed characters. **9**: Infructescence, scale bar = 2 cm. **10**: Berry, side view, scale bar = 5 mm. **11**: Seed, side view, scale bar = 2 mm.

black circles). *Dracontium polyphyllum* L. also occurs in Pará, but extends much further west and northwest into Amazonas state, the Guianas and Venezuela. It differs from *D. nivosum* most clearly by its much shorter styles, which project above the tepals only up to 2 mm, whereas in *D. nivosum* the styles are 4 to 5.5 mm longer than the tepals. Figure 8 shows the flowers of the Ceará plant at male anthesis, with the anthers forming a dense layer above the initial level of the tepals which have now been so stretched as to be visible only as pink tips. U. Mehlig's excellent photograph of the flowers of *D. nivosum* from Pará (speciesLink 2015, *Mehlig 1505*) shows the flowers at the earlier stage of female anthesis before the emergence of the anthers.

Our report confirms an eastward range extension for *D. nivosum* of 558 km (geodesic distance) and its occurrence in a markedly different ecological situation from that previously known (Figure 12, green circles; Table 1). Whereas the Pará and Maranhão collections occur between 5 and 148 m elevation in Amazonian *terra firme* moist forest (Figure 12, black circles), the Ceará populations were found at 580–870 m elevation in montane *brejo* moist forest (Figure 12, green circles; Table 1). Areas of *brejo* forest are scattered across the dominant semi-arid caatinga domain of Northeast Brazil, and occur wherever high ground (500–1,100 m elevation) lies in the path of humid trade winds from the Atlantic Ocean, creating cooler conditions that give rise to orographic rainfall and high atmospheric humidity with frequent mists and heavy dews. They are conjectured to be natural remnants of forests that were more widespread during cooler and more humid periods of the Quaternary and at least partially continuous with the Amazon and Atlantic forests at various times (Andrade-Lima 1982; Andrade and Mayo 2010).

Given the wide disjunction, higher altitude and different forest type of the Ceará plants, some genetic divergence from the Amazonian populations is to be expected. The smaller inflorescences of the *brejo* forest plants might be the result of cooler temperatures and more seasonal rainfall, although the leaves are as big as those of the Amazonian plants. The darker berry colour may be due to our collections not being at full maturity, but this remains to be confirmed.

Zhu and Croat (2004) reported flowering from May to June and fruiting from December to March for Amazonian plants. To this may be added the October flowering of U. Mehlig's specimens from Bragança in eastern Pará (*Mehlig 1505* illustrated at SpeciesLink 2015). In Ceará fruiting plants were observed in the field in May and a cultivated plant flowered in June.

The four *brejo* forest fragments where *D. nivosum* has been collected are remnants of a previously more extensive *brejo* forest that once covered most of the eastern side of the northern part of the Chapada da Ibiapaba and which is now mostly agricultural land. Local human pressure on the remaining forest habitat continues. During our fieldwork we saw no more than five plants at each locality, although a demographic study is needed to investigate this further. Approximately 40–50 berries per infructescence (Figure 9) are produced, each with (2–) 3 to 4 seeds.

Spatial analysis and IUCN conservation assessments (IUCN Standards and Petitions Subcommittee 2010) made using GeoCat (Bachman et al. 2011) gave the following results. Extent of Occurrence (EOO) was estimated at 356,392 km^2 based on 20 collections from 15 localities, representing the known species range, giving an assessment of Least Concern (LC). Area of Occupancy (AOO) was 60 km^2, based on the IUCN default 2 × 2 km cell, giving an assessment of Endangered (EN). At the GeoCat 50 km auto-value cell width the AOO becomes 32,500 km^2, giving an assessment of LC. Most collections of the species are from Pará state and humid forest cover is still extensive there, justifying a larger cell width. Only a single collection is known from Maranhão state and the status of its habitat is currently unknown. In Ceará (Figure 12) the surviving fragments of humid forest where *D. nivosum* has been recorded are no larger than 4 km^2, so a 2 km cell width is appropriate. If only the Ceará records are considered (5 collections from 4 localities), the EOO is 41.4 km^2 (Critically Endangered CR) and the AOO 16 km^2 (Endangered EN).

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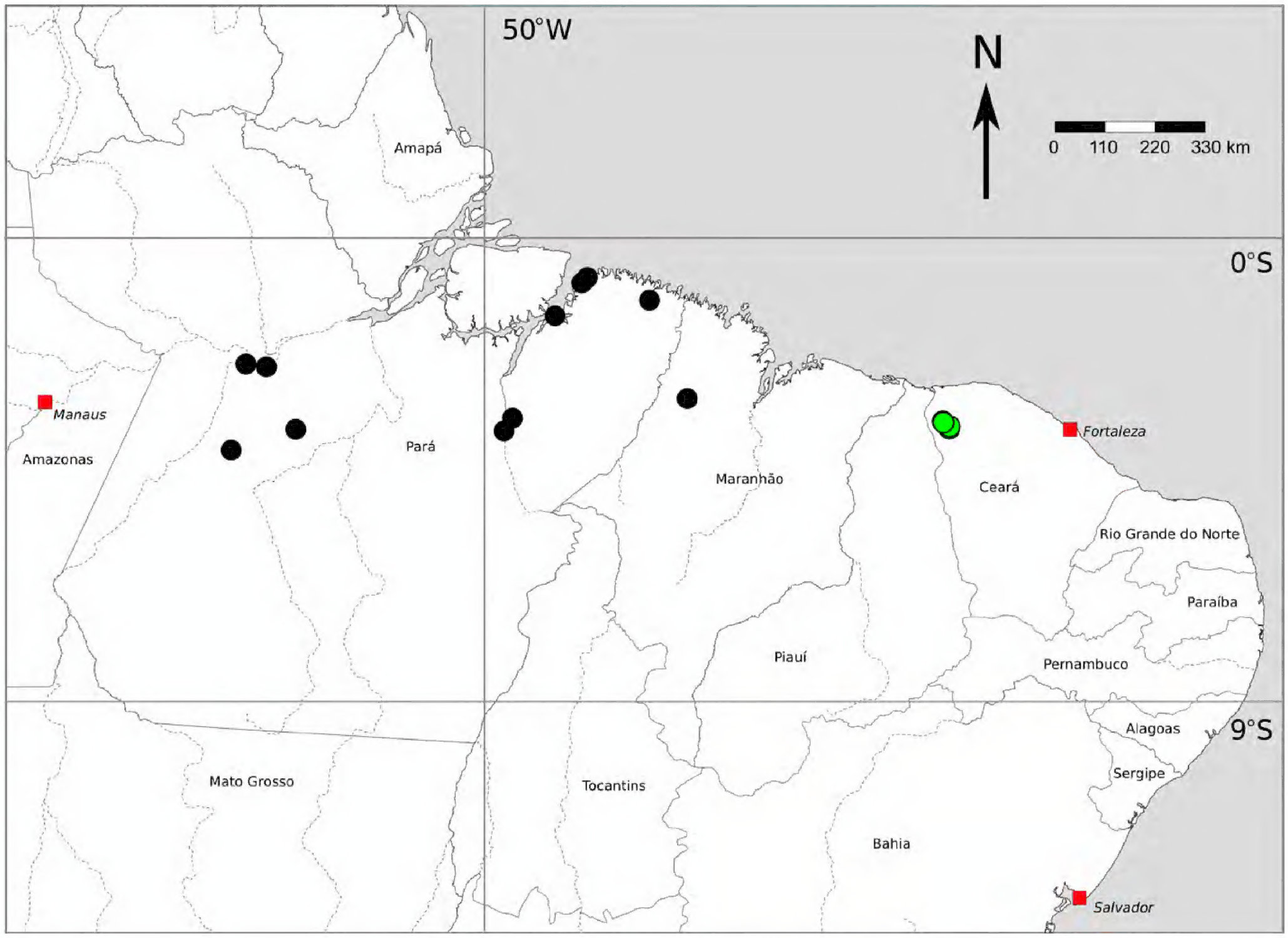

Figure 12. Distribution map of *Dracontium nivosum* showing the four Ceará localities (light green circles) and 11 localities added from the speciesLink (2015) database (solid black circles) showing previously known range. State boundaries shown in solid lines, major rivers in dashed lines, major cities as red squares. Plotted with SimpleMappr (Shorthouse 2010). Map projection: geographic; datum WGS84.

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